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Climate risk measures and main data providers

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Introduction

ESG (Environmental, Social, and Governance) ratings are becoming increasingly significant in guiding financial investment decisions. However, numerous studies have highlighted discrepancies in ESG ratings across different data providers, primarily due to variations in the methodologies they employ. To address this issue, we provide a summary of the key ESG data providers, focusing on two distinct aspects: ESG ratings for firms and ESG ratings for countries. These two topics are essential in empirical analysis to attempt to integrate both dimensions—firm and country—into the evaluation process for assessing whether they play a significant role in defining climate risk. Moreover, this integration aids in understanding the implications for climate risk premiums in the stock market. By considering both the firm and country dimensions, we can better capture the multifaceted nature of climate risk and its impact on investment outcomes. The purpose of this report is twofold: first, we retrieve information from websites concerning the ESG criteria and methodologies of major climate indicator data providers, evaluating their transparency and accountability, and highlighting the differences between public and private sources. Second, we focus on alternative measures of climate risk that should be used in empirical analysis. Indeed, ESG ratings at both the company and country levels are not the only measures of climate risk exposures. In particular, while ESG ratings or solely the Environmental dimension are often used to assess transition climate risk, they are less frequently applied to assess physical risk.

The rest of the report is organized as follows. In Section 2 we provide an overview of ESG ratings and the criteria used in their assessment. In Section 3, we discuss the main data providers for ESG firm ratings, while

Section 4 presents the primary data providers for ESG country ratings. The last section concludes.

1. ESG rating: overview

In this section, we first provide evidence of the different definitions of ESG ratings and the principles that underlie them. Second, we highlight several issues related to the use of ESG ratings in empirical analysis to assess the existence of climate risk premiums in financial markets, as previously examined in the literature.

1.1. ESG definition and *genesis*

As reported by the European Commission site[1], ESG ratings provide insights into a company's or financial instrument's sustainability performance by evaluating its exposure to sustainability risks and/or its impact on people and the environment. Moreover, some public and private provider have developed sovereign ESG rating.

ESG ratings providers use various terms such as ratings, scores, valuations and opinions to describe their assessments. Different types of ESG ratings exist:

- Combined ratings for E, S and G factors, individual ratings for specific factors (e.g., environmental), or ratings for sub-factors. In Subsection 1.1 we presented the E-S-G factors and sub-factors.
- Ratings based on a double materiality perspective (considering both risks and impacts) or a single materiality perspective (focusing solely on risks or impacts), as well as ratings aligned with international frameworks/standards.
- Ratings generated by analysts or those purely based on data analysis.

While ESG ratings are primarily developed and distributed by specialized ESG rating providers, some financial institutions also create their own ESG ratings. ESG ratings play a growing role for investors and are crucial in building confidence in sustainable investments. Investors increasingly incorporate ESG ratings into their sustainable investment strategies to account for ESG-related risks and impacts. Companies, on the other hand, use these ratings to identify operational risks, explore investment opportunities, and assess their ESG performance relative to their peers.

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[1]See: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/esg-rating-activities_en

Due to the relevance of these issues, the EU has approved new regulations on ESG rating activities to ensure that investors and other stakeholders have access to reliable and comparable information regarding the objectives (what is assessed) and methodologies (how is it assessed) of ESG ratings. Given the significance of ESG ratings in investment decisions, these regulations will promote greater transparency regarding the impact of companies on people and the environment, help reduce greenwashing, and encourage sustainable investments. Specifically, the new regulations will make ESG ratings and their methodologies more transparent and will enhance the governance and independence of ESG rating providers. Additionally, the ESG Ratings Regulation will amend the Sustainable Finance Disclosure Regulation (SFDR) to ensure that financial institutions developing and disclosing their own ESG ratings provide the same level of information as specialized ESG rating providers. Moreover, ESG rating providers offering services to investors and companies within the EU will be required to obtain authorization and supervision from the European Securities and Markets Authority (ESMA). These regulations will also bring greater clarity to the operations of ESG rating providers, particularly regarding the prevention and mitigation of conflicts of interest.

Concerning the genesis of ESG criteria, ESG investments have been developing for a long time. ESG themes were first cited by the United Nations Principles for Responsible Investment (PRI) in 2006. These principles are as follows:

- Principle 1: We will incorporate ESG issues into investment analysis and decision-making processes.

- Principle 2: We will be active owners and incorporate ESG issues into our ownership policies and practices.

- Principle 3: We will seek appropriate disclosure on ESG issues by the entities in which we invest.

- Principle 4: We will promote acceptance and implementation of the Principles within the investment industry.

- Principle 5: We will work together to enhance our effectiveness in implementing the Principles.

- Principle 6: We will each report on our activities and progress towards implementing the Principles.

As early as 1999, the United Nations Global Compact (UNGC) introduced ten key principles derived from international agreements and conventions, such as the Universal Declaration of Human Rights, the International Labour Organization's Declaration on Fundamental Principles and Rights at Work, the Rio Declaration on Environment and

Development, and the United Nations Convention Against Corruption. These Ten Principles are grouped into four main categories:

A. Human Rights

  1. Principle 1: Businesses should support and respect the protection of internationally proclaimed human rights.

  2. Principle 2: Businesses should ensure that they are not complicit in human rights abuses.

B. Labour

  3. Principle 3: Businesses should uphold the freedom of association and the effective recognition of the right to collective bargaining.

  4. Principle 4: Businesses should work towards the elimination of all forms of forced and compulsory labour.

  5. Principle 5: Businesses should work towards the effective abolition of child labour.

  6. Principle 6: Businesses should eliminate discrimination in respect of employment and occupation.

C. Environment

  7. Principle 7: Businesses should support a precautionary approach to environmental challenges.

  8. Principle 8: Businesses should undertake initiatives to promote greater environmental responsibility.

  9. Principle 9: Businesses should encourage the development and diffusion of environmentally friendly technologies.

D. Anti-Corruption

  10. Principle 10: Businesses should work against corruption in all its forms, including extortion and bribery.

By 2015, the Sustainable Development Goals (SDGs) established seventeen sustainability objectives and set a global framework for sustainable development, aiming to enhance quality of life and create a more sustainable future by 2030. Although broader in scope, the SDGs included specific targets—169 in total—each with distinct indicators to monitor progress. The adoption of the SDGs signified a change in the socio-political perspective; ESG considerations were no longer just topics of discussion but were now elements that could and should be measured. These goals are as follows:

- SDG 1: End poverty in all its forms everywhere.
- SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
- SDG 3: Ensure healthy lives and promote well-being for all at all ages.
- SDG 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- SDG 5: Achieve gender equality and empower all women and girls.
- SDG 6: Ensure availability and sustainable management of water and sanitation for all.
- SDG 7: Ensure access to affordable, reliable, sustainable, and modern energy for all.
- SDG 8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
- SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
- SDG 10: Reduce inequality within and among countries.
- SDG 11: Make cities and human settlements inclusive, safe, resilient, and sustainable.
- SDG 12: Ensure sustainable consumption and production patterns.
- SDG 13: Take urgent action to combat climate change and its impacts.
- SDG 14: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
- SDG 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and biodiversity loss.
- SDG 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.
- SDG 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

As investors increasingly demanded climate-related financial disclosures from companies, regulators responded by introducing new reporting requirements. In 2015, the Task Force on Climate-related Financial Disclosures (TCFD) was established to create standards for climate-related reporting for financial institutions, companies, and investors.

This principles and objectives underlie the ESG score components (or factors). In addition, the European Banking Authority (EBA) is a regulatory agency of the European Union (EU), established in 2011 in response to the global financial crisis of 2007-2008. Its main task is to ensure effective and

consistent prudential regulation and supervision across the European banking sector. In 2021[2], the EBA released a document outlining the factors that should be used in ESG scoring, highlighting the differences among various sources. **Table 1** presents this framework.

Table 1. *ESG dimensions factors.*

Source	Environmental	Social	Governance
International frameworks[1)	- GHG emissions - Energy consumption and efficiency - Air pollutants - Water usage and recycling - Waste production and management (water, solid, hazardous) - Impact and dependence on biodiversity - Impact and dependence on ecosystems - Innovation in environmentally friendly products and services	- Workforce freedom of association - Child labour - Forced and compulsory labour - Workplace health and safety - Customer health and safety - Discrimination, diversity and equal opportunity - Poverty and community impact - Supply chain management - Training and education - Customer privacy - Community impacts	- Codes of conduct and business principles - Accountability - Transparency and disclosure - Executive pay - Board diversity and structure - Bribery and corruption - Stakeholder engagement - Shareholder rights
European frameworks [2)	- GHG emissions - Energy consumption and efficiency - Exposure to fossil fuels - Water, air, soil pollutants - Water usage, recycling and management	- Implementation of fundamental ILO Conventions - Violation of UN Global Compact Principles - Inclusiveness/Inequality - Exposure to controversial weapons - Discrimination	- Anti-corruption and anti-bribery policies - Excessive CEO pay - Diversity (unadjusted gender pay gap and board gender diversity)

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[2] See https://www.eba.europa.eu/publications-and-media/press-releases/eba-publishes-its-report-management-and-supervision-esg-risks

	Environmental	Social	Governance
	- Land degradation, desertification, soil sealing - Waste production and management (hazardous, non-recycled) - Raw materials consumption - Biodiversity and protection of healthy ecosystems - Deforestation	- Insufficient whistle blower protection - Rate of accidents and number of days lost to injuries, accidents, fatalities or illness - Human rights policy - Investment in human capital and communities - Trafficking in human beings	
Industry[3]	- Consumption of materials, energy and water - Production of GHG emissions, other emissions to air and water - Production and management of waste and wastewater - Protection of biodiversity - Research and development in low-carbon and other environmental technologies	- Quality and innovation in customer relations, rights of customers to gain information about environmental issues - Human rights - Labour practices: human resource management and employee relations, diversity issues, gender equality, workplace health and safety considerations - Access to credit and financial inclusion - Personal data security	- Set of rules or principles defining rights, responsibilities and expectations between different stakeholders in the governance of the entity/sovereign - Executive pay - Board of Directors independence - Board composition and structure - Shareholder rights - Internal audit - Compensation - Bribery and corruption - Integrity in corporate conduct/conduct frameworks
Common areas[4]	- Water usage and consumption - Waste management and production	- Labour and workforce considerations - Human rights - Inequality - Discrimination	- Rights and responsibilities of directors - Remuneration - Bribery and corruption

	▪ Energy consumption ▪ Pollution ▪ Biodiversity ▪ GHG emissions	▪ Gender equality	

Sources: EBA staff based on: 1) the frameworks listed in paragraph 29 of this report, 2) Regulation EU 2020/852 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 and Draft RTS under SFDR on sustainability-related disclosures in the financial services sector; 3) EBA Market Practices Survey on Sustainable Finance and 4) EBA staff.

1.2. Issues of ESG in empirical analysis

As highlighted by Matos (2020), there has been a substantial increase in access to ESG data in recent years, which has raised concerns about data quality, the lack of data for smaller firms and the phenomenon of greenwashing—a practice where the true alignment of investments with sustainability goals is misrepresented or overstated. Potential biases in ESG ratings can be categorized as size bias, geography bias, and industry bias. Size bias arises because larger companies may receive more favourable ESG evaluations due to their ability to dedicate more resources to preparing and publishing ESG disclosures and managing reputational risks. Geography bias occurs because ESG ratings are typically higher for companies located in regions with stricter reporting requirements. Industry bias is linked to the oversimplification that can occur when ESG ratings are normalized by industry standards.

Moreover, ESG ratings can vary significantly across different data providers (see Chatterji et al. (2016); Escrig-Olmedo et al. (2019); Berg et al. (2019); Alessi et al. (2020)). Gibson et al. (2019) found that the average correlation between the overall ESG ratings of different data providers is less than 50%. Assuming that companies with high ESG scores are "good" and those with low ESG scores are "bad," Cornell and Damodaran (2020) point out that socially responsible companies tend to have lower discount rates, leading to lower expected returns for investors. Additionally, the evidence suggests that poorly performing firms are more likely to face negative consequences, such as higher discount rates or a greater likelihood of experiencing disasters and shocks. However, evidence for the integration of social responsibility into market pricing remains weak, except in cases where companies are identified as poor performers.

Using multivariate regression analysis on a dataset of European publicly traded companies over a ten-year period, Rossignoli (2024) finds that environmental disclosures are particularly valuable for financial analysts in predicting future performance for companies with high pollution levels.

The study also reveals that the transparency of environmental disclosures tends to decrease when these highly polluting firms adopt riskier business strategies.

In the following sections, we present the main data providers related to climate risk measures and exposures, with a focus on ESG data. We also considered other measures beyond ESG that are used in empirical analysis, provided by both private and public institutions. As mentioned, various factors contribute to determining E-S-G dimension scores, and each of these factors, such as CO_2 emissions, can be used separately in empirical analysis.

2. Firms ESG rating

We collect the main data providers that make available ESG ratings of companies. Our goal is to retrieve relevant information about the methodology used to compute the ESG rating, through the public website of the data providers. This is a measure of accountability and transparency.

URGENTEM is a data and analytics company that focuses on providing granular, transparent, and science-based carbon emissions data, which can be applied to ESG and climate risk assessments, in 2022 acquired by the Intercontinental Exchange (ICE). So, ICE is becoming the most relevant data provider that combine climate physical risk data (URGENTEM source) and ESG company Data. Through the geospatial platform, ICE links these risks to a wide range of asset classes, including municipals, securitized products (MBS), sovereigns, entities (public and private corporates) and real estate. However, we find it difficult to retrieve information about the methodology of computing ESG rating. The website of ICE is limited to explain the component of each ESG dimensions, nonetheless aligned to the major international indications.

The ESG score of Bloomberg coverage extends to approximately 15,000 companies, representing 90% of the global market capitalization across over 100 countries. While the primary focus is on public companies, a limited number of private companies are also included. Regarding corporate bonds, the scores cover more than 90% of Bloomberg's US and European corporate investment-grade bond indices, mapping the scores at the issuer level. Additionally, around 70,000 funds are scored using a bottom-up approach, aggregating ESG score percentiles. Bloomberg's ESG scores are regularly updated to reflect newly available data or revisions to previously disclosed information. The frequency of ESG data disclosure varies by company, as reporting typically occurs annually. Therefore,

scores are calculated and published as data becomes available. The "Latest" scores use the most up-to-date information, supplementing the most recent fiscal year's complete data with any newly disclosed details. "Fiscal Year" scores are provided once complete ESG data for a specific fiscal year is published. The overall ESG score is derived from an aggregation of Environmental (E), Social (S), and Governance (G) pillar scores. The relative weight of each pillar depends on the sector, determined by Bloomberg Intelligence's fundamental research. Each pillar is assigned a financial materiality ranking on a scale from 1 to 5, with 1 representing the highest importance. Governance (G) is ranked 3 across all sectors, as company and region-specific factors often have a greater impact on governance than industry factors. These rankings are then converted into percentage weights for the aggregation of the three ESG pillars, using a weighted generalized mean. For the aggregation of E, S, and G pillars, prioritization of issues is based on research and analysis of their potential impact in terms of probability, magnitude, and timing. Issue selection and prioritization follow a rules-based approach, determining their weight when aggregated into themes for Governance scores and the E, S, and G pillars. The process is guided by global standards like the Sustainability Accounting Standards Board (SASB) and the International Sustainability Standards Board (ISSB), complemented by disclosure frameworks such as the Global Reporting Initiative (GRI), CDP, and the Task Force for Climate-Related Financial Disclosures (TCFD). Additionally, sector-specific guidelines are reviewed, such as those from the European Public Real Estate Association (EPRA) for the real estate sector. Bloomberg's in-house research further refines the assessment of material issues, metrics, and their relative importance for scoring performance.

MSCI ESG Ratings are determined at the company level and are designed to be industry-relative. The ratings use a global seven-tier scale, ranging from AAA (the highest rating) to CCC (the lowest rating). Each company is assessed on a set of two to seven Environmental and Social Key Issues, selected from a total of 33 potential issues. These Key Issues are chosen based on the company's exposure to material ESG risks, which are influenced by industry-specific and market-specific factors. Additionally, all companies are evaluated on the Governance Pillar, which includes six Key Issues within the Corporate Governance and Corporate Behavior Themes. The Governance Pillar assessment measures the gap between a company's governance practices and best practices. The MSCI ESG Ratings consider how well a company manages its overall ESG risks and opportunities, with management efforts evaluated through governance structures, policies, targets, performance metrics, and relevant controversies. The final Company ESG Rating is a seven-point letter scale,

from AAA to CCC, which is industry-relative rather than absolute. This rating is derived from the Industry-Adjusted Company Score, which normalizes the Weighted Average Key Issue Score (WAKIS) relative to industry peers. The WAKIS is calculated based on the weighted average of scores on selected Environmental and Social Key Issues and the Governance Pillar Score. The Governance Pillar Score, ranging from 0 to 10, assesses a company's overall governance based on deductions from key metrics in the Corporate Governance (Ownership & Control, Board, Pay, and Accounting) and Corporate Behavior (Business Ethics and Tax Transparency) themes. Key Issue Scores, also ranging from 0 to 10, evaluate a company's exposure to ESG risks or opportunities and its ability to manage them, using both the Key Issue Exposure Score and the Key Issue Management Score.

Bloomberg, and MSCI have collaborated on the development of the market's first fixed income index family to incorporate measures of ESG risk and exposures.

The methodology for Sustainalytics' ESG ratings can be downloaded from their website, following registration through a form. The ESG Risk Ratings approach to materiality is assessed through two key dimensions: Exposure and Management. The Exposure dimension reflects the degree to which a company is exposed to material ESG risks, both at the overall and individual Material ESG Issues (MEI) level. Management, the second dimension, evaluates how effectively a company is addressing its ESG risk exposure. This dimension is based on a set of commitments, actions, and outcomes that demonstrate a company's ability to manage the ESG risks it faces. Management scores are derived from both management indicators—such as policies, management systems, and certifications— and outcome-focused indicators, which measure performance in quantitative terms (e.g., CO_2 emissions or intensity) or through the company's involvement in controversies, reflected in event indicators. The final ESG Risk Ratings reflect unmanaged risk, which refers to the portion of material ESG risk that a company has not yet mitigated. The scoring system follows a hierarchical or waterfall structure with four levels, which can be applied both to individual issues and the overall score. To account for the evolving nature of ESG risks, Sustainalytics conducts an annual review of its ESG Risk Ratings model components, known as the ESG Risk Ratings Review.

In our analysis, we find that LSEG is the most transparent private data provider. Following its acquisition of Refinitiv in 2021, LSEG has made its methodology document, developed in December 2023, readily accessible. This document details the steps used to construct their ESG rating scores. LSEG's ESG coverage encompasses over 15,500 public and private

companies globally. Their ESG scores are a transparent, data-driven assessment of companies' relative ESG performance and capabilities, incorporating industry materiality and company size biases. The methodology for LSEG's ESG scoring adheres to several key calculation principles. Additionally, an overall ESG Controversy (ESGC) score is calculated, which adjusts the ESG score for news controversies that materially affect corporations. LSEG evaluates over 630 company-level ESG metrics, with 186 metrics (details available in the ESG glossary upon request) being the most comparable and material for each industry. These metrics are used to determine the overall company assessment and scoring process. The ESGC score provides a comprehensive evaluation of a company's ESG performance by integrating reported data across ESG pillars and factoring in controversies reported in global media. The primary aim of the ESGC score is to adjust the company's ESG performance score based on significant, material ESG controversies. This adjustment is made by incorporating the effects of major controversies into the final ESGC score. If a company is involved in a scandal during the year, it is penalized, affecting its overall ESGC score and rating. The impact of such events may persist into the following year if related developments continue, such as lawsuits, ongoing legislation disputes, or fines. New media materials are continuously captured as the controversy evolves. When a company faces ESG controversies, the ESGC score is calculated as a weighted average of the ESG score and the controversy score for each fiscal period, with recent controversies having a greater impact. If there are no controversies, the ESGC score equals the ESG score.

The methodology for calculating the LSEG ESG scores can be broken down into several key steps:

1. ESG Category Scores: ESG performance is assessed based on a series of Boolean (Yes/No) and numeric data points, which are aggregated into percentile scores. Boolean data points are converted into numeric values, and a default value is applied when no data is reported. This process is used to calculate scores across 10 different ESG categories (e.g., emissions, workforce, human rights).

2. Materiality Matrix: The material importance of ESG factors is evaluated by a magnitude matrix, which assigns weights to ESG categories based on industry-specific factors. Each category's weight is calculated based on industry-relevant data, and updated annually.

3. Pillar and Overall ESG Scores: The overall ESG score is calculated by aggregating category scores into three pillar scores (Environmental, Social, and Governance). Each category within

these pillars is weighted according to industry-specific relevance, and the final ESG score is derived from these weighted pillar scores.

4. Controversy Scores: Companies involved in significant ESG-related controversies receive a separate controversy score, which is integrated with their ESG score to produce an ESGC score. This reflects how controversies influence a company's overall ESG performance.

5. ESGC Score Calculation: The ESGC score combines the ESG score and the controversy score, with adjustments made depending on the severity of the controversies. If a controversy is more severe than the ESG score, the ESGC score will reflect this.

3. Countries ESG rating

Many data providers that create ESG scores at the company level also offer ESG ratings at the country level, but information on this is often hard to find. The World Bank is an open-source platform that provides extensive data on ESG criteria for countries. Their ESG Data Draft dataset covers 17 key sustainability themes across environmental, social, and governance categories. To help financial markets align with global sustainability goals, the World Bank is enhancing data and analytics on countries' sustainability performance. The dataset has been updated with more years of data, with over 30 indicators having 2022 data available, and many others spanning up to 2020. Time-series data, starting from 1960, allow analysis of ESG trends. Additionally, country-specific indicators, such as population growth and GDP per capita, have been updated. New data have been added for countries like Puerto Rico (e.g. renewable energy output) and Greenland (e.g., agricultural land share). The World Bank is continuously expanding its data offerings to improve insights into countries' sustainability and their impact on investments. It's important to note that the World Bank data do not represent a pre-calculated ESG rating. Instead, the World Bank provides raw data that enables users to assess and analyse various variables contributing to the formation of an ESG rating. This comprehensive dataset enables accountability across environmental, social, and governance factors by offering detailed indicators. Users can use these indicators (presented in Table 2) to conduct their own assessments and evaluations, leading to informed decisions on a country's sustainability performance, rather than relying on a pre-determined ESG score.

Table 4. *Complete list of variables provided by World Bank concerning ESG.*

Environmental
Emissions & pollution
CO_2 emissions (metric tons per capita)
GHG net emissions/removals by LUCF (Mt of CO_2 equivalent)
Methane emissions (metric tons of CO_2 equivalent per capita)
Nitrous oxide emissions (metric tons of CO_2 equivalent per capita)
PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)
Energy use & security
Electricity production from coal sources (% of total)
Energy imports, net (% of energy use)
Energy intensity level of primary energy (MJ/$2017 PPP GDP)
Energy use (kg of oil equivalent per capita)
Fossil fuel energy consumption (% of total)
Renewable electricity output (% of total electricity output)
Renewable energy consumption (% of total final energy consumption)
Climate risk & resilience
Population density (people per sq. km of land area)
Cooling Degree Days
Heating Degree Days
Heat Index 35
Standardised Precipitation-Evapotranspiration Index
Land Surface Temperature
Coastal protection
Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
Proportion of bodies of water with good ambient water quality
Food Security
Agricultural land (% of land area)
Agriculture, forestry, and fishing, value added (% of GDP)
Food production index (2014-2016 = 100)
Natural capital endowment & management
Adjusted savings: natural resources depletion (% of GNI)
Adjusted savings: net forest depletion (% of GNI)
Annual freshwater withdrawals, total (% of internal resources)
Forest area (% of land area)
Mammal species, threatened
Terrestrial and marine protected areas (% of total territorial area)
Tree Cover Loss
Total variables: 31

Social
Access to Services
Access to clean fuels and technologies for cooking (% of population)
Access to electricity (% of population)
People using safely managed drinking water services (% of population)
People using safely managed sanitation services (% of population)
Demography
Fertility rate, total (births per woman)
Life expectancy at birth, total (years)
Population ages 65 and above (% of total population)
Education & skills
Government expenditure on education, total (% of government expenditure)
Literacy rate, adult total (% of people ages 15 and above)
School enrolment, primary (% gross)
Employment
Children in employment, total (% of children ages 7-14)
Labor force participation rate, total (% of total population ages 15-64) (modelled ILO estimate)
Unemployment, total (% of total labour force) (modelled ILO estimate)
Health & Nutrition
Cause of death, by communicable diseases and maternal, prenatal and nutrition conditions (% of total)
Hospital beds (per 1,000 people)
Mortality rate, under-5 (per 1,000 live births)
Prevalence of overweight (% of adults)
Prevalence of undernourishment (% of population)
Poverty & Inequality
Annualized average growth rate in per capita real survey mean consumption or income, total population (%)
Gini index
Income share held by lowest 20%
Poverty headcount ratio at national poverty lines (% of population)
Total variables: 22

Governance
Economic Environment
GDP growth (annual %)
Individuals using the Internet (% of population)
Gender
Proportion of seats held by women in national parliaments (%)
Ratio of female to male labor force participation rate (%) (modelled ILO estimate)
School enrolment, primary and secondary (gross), gender parity index (GPI)
Unmet need for contraception (% of married women ages 15-49)
Government Effectiveness
Government Effectiveness: Estimate
Regulatory Quality: Estimate
Human Rights
Strength of legal rights index (0=weak to 12=strong)
Voice and Accountability: Estimate
Economic and Social Rights Performance Score
Innovation
Patent applications, residents
Research and development expenditure (% of GDP)
Scientific and technical journal articles
Stability & Rule of Law
Control of Corruption: Estimate
Net migration
Political Stability and Absence of Violence/Terrorism: Estimate
Rule of Law: Estimate
Total variables: 18

Sources: https://esgdata.worldbank.org/data/framework?lang=en

4. Other measures of climate risk

Many data providers offer ESG ratings that can be used as a measure of climate risk, particularly transition risk, in empirical analyses. However, when available, it is also possible to focus on specific indicators instead of the full ESG rating. For instance, one could analyse only CO_2 emissions (E component), the percentage of female employees (S component) or the level of transparency (G component). In this section, we aim to present alternative measures that extend beyond the ESG framework and are more closely related to assessing physical risk. These indicators primarily focus on a country's (or region's) exposure to climate-related physical events. For example, metrics related to geographical vulnerability to floods, droughts, or rising sea levels provide a more accurate reflection of

physical risk compared to transition risk tied to sustainability policies. The purpose of these indicators is to offer a broader understanding of the physical vulnerabilities that countries or regions may face in the context of climate change.

One of the most recent indicators related to physical risk concerning countries' exposure to adverse climate phenomena is the E3CI (European Extreme Events Climate Index), developed by the International Foundation Big Data and Artificial Intelligence for Human Development (IFAB). The index focuses on European countries, with a particular focus on Italy and its regions. The evaluation of the components uses ERA5, the fifth-generation atmospheric reanalysis from the European Centre for Medium-Range Weather Forecasts (ECMWF). ERA5 includes hourly data on various atmospheric parameters, along with uncertainty estimates, and is accessible through the Climate Data Store of the Copernicus Climate Change Service (C3S). ERA5 is updated daily with a latency of approximately 5 days, allowing for continuous updates of the components that make up the E3CI. There are 7 indicators that contribute to the determination of the E3CI index. Each of them, after being calculated, is standardized. They are listed below:

- Heat Stress (HS): Measures the exceedance of daily maximum temperatures over the 95th percentile of past records.
- Cold Stress (CS): Measures the exceedance of daily minimum temperatures below the 5th percentile of past records.
- Drought (SPI-3): Uses a 3-month Standard Precipitation Index to assess deviations from normal precipitation, with lower values indicating drought.
- Extreme Precipitation (EP): Measures the exceedance of daily precipitation over the 95th percentile of past records.
- Extreme Winds (LLI): Uses the Local Loss Index to measure the intensity of extreme wind events based on daily maximum wind speed exceedances.
- Hailstorms Leading Conditions (ES): Assesses the exceedance of the Significant Hail Parameter (SHIP) indicator values beyond a threshold.
- Forest Fire Leading Conditions (EF): Evaluates the exceedance of the Fire Weather Index (FWI) beyond a high danger threshold.

The E3CI is a composite index that averages the standardized anomalies from all the above components to provide an overall assessment of extreme climate events. Values greater than 1 indicate anomalies and are considered critical; therefore, they are associated with extreme climate events.

Similar to E3CI, the European Climate Adaptation Platform, Climate-ADAPT, is a partnership between the European Commission and the European Environment Agency (EEA). It is maintained by the EEA with support from the European Topic Centre on Climate Change Impacts, Vulnerability, and Adaptation (ETC/CCA). The platform aims to assist Europe in adapting to climate change by providing access to and sharing of data and information on:

- Expected climate change impacts in Europe
- Current and future vulnerabilities of regions and sectors
- EU, national, and transnational adaptation strategies and actions
- Adaptation case studies and potential adaptation options
- Tools to support adaptation planning

The platform features a database with quality-checked information that is easily searchable. Climate-ADAPT offers various specific data related to climate change and the environment, including:

a) Temperature and Precipitation: Historical data and future projections of average temperatures and precipitation for various regions, including monthly or annual analyses and trends over time.
b) Air Quality: While not the main focus, some data related to air quality may be available through specific projects and initiatives. This may include information on pollutants such as PM2.5, PM10, NO2, and O3.
c) Sea Level and Flooding: Information on changes in sea levels and assessments of flood risk based on future climate scenarios.
d) Extreme Weather Events: Data on the frequency and intensity of extreme weather events, such as heatwaves, storms, and floods.
e) Environmental Health: Sections may include data on how climate change affects human health and the environment, including the spread of climate-related diseases.
f) Biodiversity and Ecosystems: Information on the impact of climate change on biodiversity and ecosystems, including changes in species and natural areas.

This data is often presented through interactive maps, charts, and detailed reports. For specific data like air quality, consulting other dedicated platforms for monitoring atmospheric pollution, such as national or local networks, may also be beneficial. Additionally, Climate-ADAPT's country profiles provide a snapshot of national adaptation actions, offering a selection of information for each country along with links to public submissions where all information and additional files are accessible.

Another global measure of climate risk exposure is represented by the ND-GAIN (Notre Dame Global Adaptation Initiative) indicators. ND-GAIN evaluates a country's vulnerability and readiness, which together assess transitional risk. Vulnerability refers to a society's propensity to be negatively impacted by climate hazards, while readiness measures the ability to effectively use investments for adaptation, influenced by a stable and efficient business environment. ND-GAIN evaluates vulnerability across six sectors: food, water, health, ecosystem services, human habitat, and infrastructure. Each sector is assessed with six indicators covering exposure to climate hazards, sensitivity to impacts, and adaptive capacity. Exposure measures how much society is stressed by changing climate conditions, sensitivity shows sector and population dependence on climate-sensitive factors, and adaptive capacity assesses the ability to adjust and mitigate damage. ND-GAIN also measures overall readiness through three components: economic readiness (ability to attract private investment), governance readiness (stability of institutions and public services), and social readiness (conditions that support effective investment use). The process for creating the index is transparent, involving data collection, error correction, data transformation, and handling of missing data through interpolation, with baseline values adjusted based on observed data ranges and percentile values as needed.

Conclusions

Financial investors are increasingly concerned with the climate risk exposure of the companies or countries in which they allocate their assets. Numerous public and private data providers develop a variety of indicators to assess this exposure. The most prominent and frequently utilized measure is the ESG rating. However, it is also possible to focus on specific components of ESG ratings. At the country level, additional physical climate risk indicators have been developed to provide a more comprehensive analysis of a nation's vulnerability to climate-related events. In our research, we collected data from several major data providers, which are summarized in Table 3.

We can draw two main conclusions:

1. As discussed in Section 1, the data provided by different sources can vary significantly due to the distinct methodologies employed in constructing ESG ratings. Ideally, having access to data from multiple providers and utilizing statistical or machine learning techniques to select the most appropriate ESG score for a specific company would be optimal.

2. Private data providers often lack transparency and accountability in their methodology, in contrast to public providers, which tend to offer greater clarity in their approach. This lack of transparency can hinder researchers from accessing critical information necessary for the implementation of robust empirical models.

3. Data related to individual companies, such as ESG ratings, typically have an annual frequency and are often calculated using financial data from the previous fiscal year. It is rare to find measures with a higher frequency.

4. Finally, we believe that a more comprehensive approach to assessing the existence of a risk premium in the stock market should consider both company-specific aspects and the geographical region in which the company operates. This would allow the consideration of both proxies for transition risk (ESG ratings) and proxies for physical risk, which are generally not developed for individual companies. However, this approach is often hindered by the frequency of available data.

Table 3. *Highlights of data providers analysed.*

Data provider	Country coverage	ESG score	Other measure	Country level	Companies level	Public (PU) Private (PR)
Bloomberg	Global	X		X	X	PR
ADAPT	Europe		X	X		PU
E3CI	Europe		X	X		PU
Eurostat	Europe		X	X		PU
ICE	Global	X		X	X	PR
LSGE	Global	X		X	X	PR
MSCI	Global	X		X	X	PR
ND-GAIN	Global		X	X		PU
Sustainalytics	Global	X		X	X	PR
World Bank	Global	X		X		PU

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Sitography

The information regarding the climate change measurement indices was directly retrieved from the websites of the data providers listed below:

Bloomberg: https://www.bloomberg.com

E3CI: https://climateindex.eu/

Eurostat: https://ec.europa.eu/eurostat

ICI: https://www.ice.com/index

LSGE: https://www.lseg.com/en/data-analytics/refinitiv

MSCI: https://www.msci.com

ND-GAIN : https://gain.nd.edu

Sustainalytics: https://www.sustainalytics.com

World Bank: https://www.worldbank.org

For technical definitions, we referred to the following international institutions' websites:

Climate ADAPTA: https://climate-adapt.eea.europa.eu/en

European Environmental Agency : https://www.eea.europa.eu/en

NASA : https://science.nasa.gov/climate-change/

Principles for Responsible Investments: https://www.unpri.org/

United Nations Department of Economic and Social Affairs Sustainable Development: https://sdgs.un.org/goals

United Nations Global Compact: https://unglobalcompact.org

Conflict of interest

The authors declare that they have no conflict of interest.

Availability of data and materials

Not applicable.

Code availability

Not applicable.